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REPORT
of the
Sixth International Conference of the CMEA Member Countries
and Yugoslavia on the Automation of Production Processes
and Control Functions in the Iron and Steel Industry

STATE OF THE ART AND BASIC TRENDS IN THE AUTOMATION OF TECHNOLOGICAL PROCESSES AND PRODUCTION CONTROL IN THE IRON AND STEEL INDUSTRIES OF THE CMEA MEMBER COUNTRIES AND YUGOSLAVIA *

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The Sixth International Conference of the Member Countries of the Council for Mutual Economic Assistance (CMEA) and Yugoslavia on the Automation of Production Processes and Control Functions in the Iron and Steel Industry takes place during the Council's thirtieth anniversary year.

CMEA's activities in the area of ferrous metallurgy have been extremely far-reaching. Aimed at broadening the basis of economic, scientific and technical co-operation among the member countries, these activities have developed successfully over the entire thirty-year period of the Council's existence. Co-operation in this area has become particularly close since the establishment, in 1956, of the Council's Permanent Commission on the Iron and Steel Industry. As part of the programme to co-ordinate co-operative efforts to introduce automation in metallurgical production, in 1962 the Commission set up a permanent working group and in 1971 an Automation Section.

The Fifth International Conference of CMEA Member Countries and Yugoslavia on the Automation of Production Processes and Control Functions in the Iron and Steel Industry, which was held in 1974 in Berlin, the capital of the German Democratic Republic, reviewed the work that had been accomplished during the period between the fourth and fifth conferences and set the course for the work of the next few years. In addition, the Conference prepared a report containing specific proposals on the further development of automation programmes, a report largely based on the recommendations developed by the section that had been established to deal with the automation of production processes and control functions in the iron and steel industry.

In November 1974, CMEA's Permanent Commission on the Iron and Steel Industry approved the work of the Fifth Conference and recommended to the member countries and Yugoslavia the following courses of action:

- The use in their iron and steel industries, wherever economically and technically expedient, of automation systems and devices designed and produced in series in the CMEA countries and Yugoslavia, as indicated in the report of the Conference and displayed at the Exhibition of Automation Systems;
- The implementation, when planning research and development programmes in the area of iron and steel industry automation, of the recommendations put forward at the Conference, keeping in mind the advisability of first assessing the results anticipated from the introduction of the automation systems and devices to be developed, primarily from the point of view of improved quality of output and higher labour productivity in the industry.

During the period that has elapsed since the Fifth Conference the extent of automation in the iron and steel plants of the CMEA countries and Yugoslavia has continued to increase. A considerable amount of work has been accomplished in these countries on the implementation of the measures referred to in the report of the Fifth Conference.

This period has been marked in particular by the development and introduction at the plant level of automation systems and devices, and also local and comprehensive systems bringing substantial improvements in the performance efficiency of metallurgical equipment. Solutions have been found to a great many research and development problems pertaining to the

automation of technological processes and production control. The member countries have concentrated their efforts on a number of current areas of investigation where there are opportunities for increased productivity and improved quality. Specifically:

- The variety and number of series-produced general-purpose automation systems and devices which are used in the iron and steel industry have been substantially increased;
- A number of special new devices and local automation systems have been developed and placed in operation at various steel mills;
- Automated systems for the control of technological processes (ASCTP systems) and automated production-control systems (APCS systems) have been developed and introduced;
- The first comprehensive automated control systems (CACS systems) combining the functions of ASCTP and APCS systems have been designed and are being introduced;
- Important practical results have been achieved in the design and operation of branch-wide (sectoral) automated control systems (BACS systems);
- The scientific principles for the design of all-level systems using systems analysis and econometric methods have been formulated, and a methodology for the development of automated control systems (ACS systems), including the determination of the technical specifications, has been devised;
- A number of modern automation systems and computers have been produced, including such computers as the ES 1010, ES 1020, ES 1021, ES 1022, ES 1030, ES 1032, ES 1033, ES 1040, M-600, M-700, R-4000, ODRA-1305, Feliks-256, Feliks-512 and others that are being series-produced in the CMEA countries.

The work carried out by the Automation Section has been a major factor in implementing the recommendations of the Fifth Conference through the organized co-operation of the member countries. During the period between 1975 and 1978 the Section focused its efforts on ensuring that the principal automation development programmes approved by the Conference in November 1974 would be fully carried out.

A positive factor in implementing the measures called for in the last Conference's report has been the preparation by the Section of the report entitled "State of the art in production-process and control automation

in the iron and steel industries of the CMEA countries and Yugoslavia and other countries, and measures for the further development of automation in this industry." As set forth in the body of this report and later approved by the Commission, the major guidelines governing the further efforts of the CMEA countries and Yugoslavia to develop improved systems for the automation of production processes and control functions in the iron and steel industry have contributed to the implementation of the plan of action adopted by the Fifth Conference.

In this connexion, the Automation Section has begun a programme to determine the rational (i.e. maximum optimal) extent to which metallurgical processes should be automated. Arrangements have been made for an exchange of information between delegations from the CMEA countries and Yugoslavia on the most effective automatic systems.

The temporary working group has surveyed the current situation with regard to automation systems and devices and has organized an exchange of experience regarding the operation of this equipment at the mills.

Because of the constantly accelerating pace of scientific and technical advances in the metal-consuming branches of industry, and the tightening of the demands of the machinery manufacturers in respect of the quality of the steel they use as their principal construction material, the basic future trend in the ferrous metallurgy sector will be towards a wider range of metal products of radically improved quality.

The need for the even faster development of comprehensive automation systems is predetermined by the intimate interdependence of the various factors which have a bearing on technology and production control processes in the iron and steel industry, an interdependence that stems from the high unit capacity of the plants being built, the heavy volume of orders for a wide range of finished products, and the presence of severe disturbing effects in processes characterized by high speed and great intensity.

This explains why the Sixth International Conference selected as its motto the words "In the iron and steel industry, automation means efficiency and quality" in order to reflect the great importance of automation in promoting further progress in this branch.

It is essential that in their future co-operation in the area of automation the CMEA countries and Yugoslavia should direct their efforts towards carrying out the measures discussed in this report. It will be the task of the experts representing these countries in the Automation Section to find the working modes and methods to speed the implementation of these recommendations.

Present development status of automation in the iron and steel industries of the CMEA countries and Yugoslavia. Principal objectives and tasks of the Sixth International Conference

The production of ferrous metals occupies an important place in the economies of the CMEA countries. Metallurgy is an integral part and leading branch of heavy industry, which has been and remains the basis of the economic strength of the countries of the socialist commonwealth.

During the period that has elapsed since the Fifth International Conference of the CMEA Member Countries and Yugoslavia on the Automation of Production Processes and Control Functions in the Iron and Steel Industry, this sector has expanded even further. In 1978 the CMEA countries produced 146.4 million tonnes of iron, 211.3 million tonnes of steel and 152.6 million tonnes of finished rolled metal.

The socialist countries accounted for approximately 30.6 per cent of world-wide steelmaking.

It is expected that the next few years will witness the extensive use in the iron and steel industry of new and advanced metallurgical processes These include: steelmaking in bottom-blown converters and in continuous-action steel-smelting units, continuous smelting of sponge iron in electric arc furnaces, remelt processes for the production of high-quality special-purpose metal, the production of protectively coated sheet and high-grade rolled metal, and a number of other processes.

These innovations will lead to structural changes in ferrous metal production and to an increase in the output of the most economical types of rolled metal products and pipe.

The common features of all these processes are: high intensity, the performance of the related operations as part of what is predominantly a continuous cycle, the need to perform the processes under strictly stable and controlled conditions, and the need to ensure a finished product of excellent quality and uniform characteristics.

These features demand accurate and reliable verification of production parameters and hence automation. Unlike the traditional methods of the iron and steel industry, many of the new processes are virtually impossible without automation.

Modern automated ASCTP and APCS systems are based on the use of computers. The most advanced and promising computer systems employ adaptive programmes. The linkage between the control computer and the production unit it operates must provide for the monitoring of a large number of parameters, while allowing for a rational combination of operating speed and priority programming. Operating speed and the flexibility of the input/output system must also be properly matched; input/output response time must be taken into account in the information exchange between the computer and its various peripheral systems. The computer link must function with no loss of machine time, a requirement that can only be met through the use of high-capacity memories. Modularly designed software is an indispensable requirement for complex systems of this kind. Moreover, this software must include automatic signalling and diagnostics.

More extensive use should be made, when designing comprehensive automated control systems, of mini-computers and micro-computers as integral components of these systems. Micro-computers, for example, can be used to design industrial robots, which should generally be more widely used in order to release production personnel, free workers from heavy, dangerous and monotonous work, and improve working conditions.

It would also be desirable to make greater use of micro-processors for the design of new process sensing equipment of higher accuracy, improved reliability and increased metrological versatility.

The way to greater ACS cost-effectiveness lies in the use of standard components, programmes and equipment, the identification of common functions for different types of production operations, the development of standard data-processing techniques, etc. One of the cardinal considerations in this connexion is the standardization of software. This applies to both ASCTP and APCS systems, considering that the engineering hardware in these systems represents approximately 30-40 per cent of the cost whereas the software accounts for 60-70 per cent.

During the years that have elapsed since the Fifth Conference positive results have been achieved in the automation of technological processes and production control.

Review of the implementation of the measures called for by the Fifth International Conference on Automation and their effect on raising the level of automation

The Sixth International Conference of the CMEA Member Countries and Yugoslavia on the Automation of Production Processes and Control Functions in the Iron and Steel Industry reviewed the accomplishments of the previous period and found that the measures recommended at the preceding Conference had been or were being carried out in the CMEA countries and Yugoslavia.

Specifically, these countries had undertaken the following major programmes:

In the area of sinter plant automation it was necessary, in order to produce high-quality sinter, to develop the first ASCTP systems for sinter plants and design new automation systems and devices for the quality-control of the sinter charge and final sinter, the most important of these systems being:

- A system for regulating the completeness of the sintering process;
- A system for regulating the cooling of the sinter;
- A system to analyse the chemical composition of sinter charge components, and others.

At this time, work has been completed on the development of computer-assisted systems for the automated control of technological processes, systems of the first two types mentioned above have been put into operation, and improvements have been made in the design of batching devices and conveyor scales for use with charge materials.

In the area of blast-furnace operations there was a need, in order to stabilize the quality of the iron produced and cut back on coke consumption, to develop systems for controlling the make-up and delivery of the charge, for monitoring and blending the charge components, for regulating the thermal conditions of the furnace and the flow of natural gas and fuel-oil through the tuyeres, and for monitoring the temperature of the hot blast to 1,500° C, as well as a number of other new systems for process automation in blast-furnace shops.

At this time, work has been completed on the design of computer-assisted systems for the automatic monitoring of coke moisture content, the control of charge make-up and delivery and the batching of blast-furnace charge components, apparatus for the measurement of the temperature of the hot blast to 1,500° C and the temperature in the hood of the blast-heater to 1,700° C, gas-analysis systems for determining the chemical composition of top gases, systems for the automatic regulation of the oxygen enrichment of the blast, apparatus for monitoring the consumption rate of charge materials, and devices for adjusting the flow of natural gas and fuel-oil through the tuyeres.

In the area of basic oxygen converter steelmaking, in order to increase the efficiency of basic oxygen converter shops and the metal yield it was necessary to introduce static and dynamic systems for the control of the basic oxygen steelmaking process and to design comprehensive converter-shop control systems as well as systems for monitoring and predicting carbon content and metal temperature.

At the present time, basic oxygen converter shops have been equipped not only with automated systems for the control of the melt process which involve advanced components and local automation features, but also additional devices, such as quantometers for the analysis of the composition of the iron, steel and slag, liquid steel samplers, high-accuracy temperature measurement devices, mechanical systems for in-ladle iron and steel temperature measurements, crane scales for the weighing of scrap, liquid pig and steel with computer recording of the readings, and systems for controlling the consumption of oxygen, the positioning of the lances and the blending of the materials.

In the area of electric steelmaking, for the purpose of increasing equipment efficiency and reducing power consumption, it was necessary to continue the equipping of the furnaces with modern thyristor-controlled and hydraulic regulators and programming devices, and to develop computer-assisted systems for controlling technological processes and the electrical performance of the furnaces.

At this time, many mills are introducing thyristor-controlled power regulators, heat probes for monitoring lining temperatures in arc furnaces, and high-speed carbon and sulphur analysers. In addition, arc furnaces are being equipped with automatic systems for the programmed control of the melt process.

In the area of open-hearth steelmaking, for the purpose of reducing melt time and producing quality steel, it was necessary to develop special monitoring devices and control systems.

At the present time, plants have introduced systems for the continuous and intermittent determination of the carbon content in steel, the monitoring and automatic batching of ferroalloys, the continuous monitoring of the temperature of the steel in the furnace, the automatic weighing of the metal on the ladle crane, the monitoring of the drawing temperature, etc.

In the area of continuous steel casting, in order to optimize the performance of the continuous billet-casting machines, it was necessary to introduce systems for controlling the level of metal in the intermediate container and the heating of the ingot and for automatically monitoring its gauge and total length and the force applied in drawing it. In addition, there was a need for systems for weighing the pouring ladles.

At the present time, systems have been introduced which automatically control the level of the metal in the intermediate container and the heating of the ingot, yield optimization systems have been put into operation, and work is in progress on the design of systems to permit the test-stand weighing of pouring ladles.

In the area of rolling-mill operations, for the purpose of increasing the efficiency of the mills, boosting the effective yield and improving the quality of rolled metal products, the need was for continued work on the development of new - and the improvement of existing - systems and devices for automation and monitoring, and for more extensive use of computers as the basis of automated production-control systems to modernize the production of hot and cold-rolled sheet and other products.

At the present time, programmes have been carried out to expand the range of equipment and to design new devices for measuring the geometrical dimensions of the stock and for the non-destructive quality-control testing of finished products; in addition, computer-assisted ASCTP systems for controlling the performance of various components of the milling units plus the pre-roll heating of the metal are being introduced.

In the area of pipe production, for the purpose of increasing the output of piping, reducing consumption ratios and improving product quality, it was necessary to continue the equipping of the apparatus used in the production of different pipe varieties with special new automation systems and devices, including systems for the optimal lay-out and grading of the skelp, and to design automatic quality-control flow lines for pipe inspection.

At the present time, computer-assisted systems for the optimal lay-out and grading of the skelp have been developed and introduced, along with systems for automatically adjusting the position of the rollers. Automatic control systems have been developed for rolling pipes with reduced wall-thickness at the ends. A system has been put into service which carries the pipe through all production phases from the skelp to the piling stage, and automatic quality-control flow lines for pipe inspection have become operational.

In the area of the power-supply equipment associated with iron and steel mills, in order to increase the efficiency of this equipment and save energy, there was a need to develop new systems and devices for automatic monitoring and control.

At the present time, automated systems of this type have been developed using new equipment based on miniaturized integrated electronic circuitry; automated systems for the metering of current-carrying equipment have been designed; the operation of steam and electrical power apparatus and steam-air compressors is being automated.

Automated systems using small computers have been developed to provide centralized monitoring and process control of the equipment employed in the chemical treatment of water, as well as systems offering programme control of turbo-compressor operation, and a system ensuring the optimal distribution of natural, coke and blast-furnace gases, including mixtures thereof, to consumers within the plant. For gas-scrubber units, waste-heat boilers and combined deaerator and water-feed apparatus, an automated computer-assisted control system has been developed to provide centralized monitoring.

Systems using electrical automation features and thermo-mechanical devices have been developed and are being introduced to ensure failure-free current for vital power-consuming equipment and stable operation of production equipment.

Plants have begun to make use of centralized control systems for their power-supply equipment based on automation and remote control.

In the area of production management in the ferrous metallurgy sector, for the purpose of improving production management, planning and record-keeping, it was necessary to develop automated production management systems for different purposes by analysing and processing data on the production, economic and technical performance of the enterprises.

At the present time, work has been carried out to improve the automated production-control systems that are being developed in all subsectors of the iron and steel industry. These improvements are based on an expanded range of functional management tasks and on programmes to design automated production-control systems using standard design principles, applied programming packages, algorithmic languages of various levels, well-researched figures for labour, time and cost factors, and methodological material pertaining to control system design.

Research in the area of iron and steel industry automation

An element of particular importance in expanding the co-operation of the CMEA countries and Yugoslavia in the automation of the iron and steel industry is their co-ordination of major scientific and technical research programmes. The following programmes were co-ordinated during the elapsed period:

- "Formulation of the requirements demanded of technological processes, metallurgical and electrical engineering equipment and automation systems" (co-ordinating country - Bulgaria; participating countries - Bulgaria, Hungary, Poland, Romania, the USSR, Czechoslovakia and Yugoslavia);
- "Development of a methodology for the comprehensive cost-effectiveness analysis of automation in the iron and steel industry" (co-ordinating country - Poland; participating countries - the German Democratic Republic, Poland, the USSR and Czechoslovakia);
- "Development and production of an automatic quality-control system for rolled stock and pipe at steel mills" (co-ordinating country - USSR; participating countries - Bulgaria, Hungary, the German Democratic Republic, Romania and the USSR);
- "Study of methods for regulating strip section and shape and development of systems for the comprehensive automatic control of continuous wide-strip hot- and cold-rolling mills" (co-ordinating country - USSR; participating countries - Bulgaria, Poland, Romania, the USSR and Czechoslovakia);
- "Methods study and development of apparatus for the multi-component compositional analysis and temperature determination of steel in an oxygen converter during the bloving process" (co-ordinating country - Czechoslovakia; participating countries - Poland, the USSR and Czechoslovakia);
- "Study and development of mathematical models of automated systems for the control of metallurgical processes" (co-ordinating countries for the various sub-programmes - Bulgaria, Hungary, the German Democratic Republic, the USSR and Czechoslovakia, participating countries - Bulgaria, Hungary, the German Democratic Republic, Poland, Romania, the USSR, Czechoslovakia and Yugoslavia);
- "Study of methods for the determination of the weight of raw material, other materials and finished products, and development of standard automatic weighing devices" (co-ordinating country - Hungary; participating countries - Hungary, Poland, Romania and the USSR).

The work on the second of these programmes was completed in 1978. As part of this programme, Soviet specialists developed a standard factor for assessing investment effectiveness. Work on the remaining programmes will be completed in 1979-1980.

For all these projects the Automation Section has co-ordinated the technical assignments and the specific work plans indicating how the programmes should be carried out. Delegations of experts from the countries involved have regularly reported to and briefed the Section at its meetings on the progress achieved during the various stages of the projects, with the result that the work plans have been corrected as required and appropriate proposals and tentative recommendations submitted.

The Automation Section has also heard survey reports or general reviews prepared by expert groups from the individual countries. These reports have discussed the current situation with regard to iron-making and steel-making automation in the delegates' countries and the future outlook in this area. Delegations have also presented papers on some of the aspects of automation of greatest current interest, specifically the following:

- "Modern automation systems and devices for the basic oxygen steel-making process" (delegation of the USSR);
- "Mathematical models for the structural optimization of high-efficiency electric steelmaking shops and electric and plasma furnaces" (delegation of the German Democratic Republic);
- "Modern automation systems and devices for use in continuous-casting plants" (delegations of the German Democratic Republic and the USSR);
- "Modern automation systems and devices for pipe-rolling operations" (delegation of Romania);
- "Modern electronic scales and weighing systems for use in production-process and control automation in the iron and steel industry" (delegation of Hungary);
- "Current situation with regard to the development and introduction of APCS and BACS systems in the iron and steel industry" (delegations of the USSR and Yugoslavia).

The results of these research programmes and the information developed in the form of surveys and reports have been and are being used by research and development organizations and iron and steel enterprises in the CMEA countries and Yugoslavia.

Technical and economic effectiveness of automation in the iron and steel industry

The rapid pace at which it is planned to expand automation activities requires sizable capital investment. In recent years there has been a steady rise in research and development outlays for the development of new automation systems and devices. In each specific case the advisability of these expenditures must be weighed in terms of genuine cost-effectiveness.

By properly assessing the cost-effectiveness of automation measures and analysing the social factors to which they give rise it will be possible to make rational use of resources, select the most promising and useful programmes and set priorities for the automation of production processes in the iron and steel industry.

Previous conferences have called attention to the problems of cost-effectiveness analysis and the complexity involved in comparing the results produced by the introduction of automation systems and devices of apparently the same type at iron and steel enterprises in the CMEA countries.

The Automation Section has completed its work on the programme "Development of a methodology for the comprehensive cost-effectiveness analysis of automation in the iron and steel industry" (co-ordinating country - Poland). Using the set of methods developed in this programme it is possible to arrive at standard calculations and work out a single approach to the evaluation of the economic effectiveness of automation. The most distinguishing feature of this methodology is its insistence on a national-economic approach to the problem of analysing automation from the standpoint of cost-effectiveness. What this means is that whatever investment option is chosen for the automation of the iron and steel industry must contribute to the enhanced efficiency of the national economy as a whole.

No analysis of cost-effectiveness can afford to overlook the social implications of automation, which are by no means always amenable to a quantitative evaluation. The easing of conditions for mill workers engaged

in heavy labour, the replacement of semi-skilled workers by highly qualified personnel for the operation of automated systems, and the improvement of plant safety - these are all factors that contribute to a better working atmosphere.

Steel industry automation is also a positive force for environmental protection.

During the period 1975-1978 the iron and steel enterprises of the CMEA countries and Yugoslavia introduced a number of highly effective automation systems and devices. For example:

Bulgaria: The Krempikovtsy Iron and Steel Combine put into operation a system for the programmed distribution of electric power among the electrodes of a 100-tonne arc furnace during the melt process. This has resulted in an increase of 40 per cent in the service life of the lining. At the same enterprise the use of flaw-detection devices on the pipe-welding line has made it possible to reduce the quantity of off-grade pipe by 2 per cent. Also at this combine, the introduction of an automated system of quality control at all phases of the conversion process has produced an additional profit of 2 million levs.

Hungary. The introduction of a thyristor power-control system for the five 15-tonne electric arc furnaces at the Lenin Iron and Steel Enterprise has led to savings in the amount of 2 million forints a year through shorter melt times and reduced power consumption. At this same complex the use of a special regulating device for control of the pulse-heated soaking pits has resulted in fuel savings of 5 million forints annually.

At the Dunaj Vasmju Iron and Steel Combine computer-assisted cutting and tracking systems are producing savings valued at 20 million forints a year. At this same establishment, the use of ultrasonic flaw-detectors on the pipe-welding line is saving one million forints a year, while the production-control system has made it possible to reduce running costs by 30 million forints a year.

German Democratic Republic. At the "Ost" Iron and Steel Combine such measures as the fitting of two blast-furnaces with radio-controlled charge level sensors, the automation of the rotary charge distributor, the automatic monitoring of tuyere burn-through and the automatic control of the fuel-oil flow rate have made it possible to reduce specific coke consumption by 26.1 kg per tonne of iron. At the Brandenburg plant the computer-assisted production-control system in the open-hearth shop has led to a reduction in melt time and ladle and ladle-crane idle time, a narrowing in the discrepancy between the nominal and actual quantity of liquid steel from ±5.75 to ±5.00 tonnes and an increase in carbon analysis accuracy of 5 per cent. By introducing the continuous measurement of the steel temperature at all open-hearth furnaces it has been possible to shorten the duration of the melt and reduce the consumption of fuel-oil. The amortization period for these systems is 0.5 years. At the pipe-rolling plant in the city of Riesa a radioisotope wall-thickness gauge has been developed and installed at mill No. 140, which, together with the introduction of technology for rolling reduced pipe with flared ends, has resulted in an increase of 3 per cent in yield.

Poland. The computerization of batching and charge-feeding control at two 3,200-m^3 blast furnaces at the Katowice Steel Plant has produced savings of 600 million zlotys a year through reduced coke consumption and increased iron yields. At the Lenin Iron and Steel Works the use of a computer to control the converter process has resulted in savings of 20 million zlotys a year. The installation of an adaptive control system for the plate-rolling operation and an automatic process-control system at the Berut and Batora plants have resulted in savings of 80 million zlotys a year through increased yields and greater furnace efficiency.

Romania. At the Galați Iron and Steel Combine the use of a computer to control the loading of a 2,700-m^3 blast-furnace, including systems for coke moisture measurements and high-accuracy batching and weighing, has resulted after one year of operation ia a reduction of 5 per cent in coke consumption and an increase of 2 per cent in furnace efficiency.

At the plate-rolling mill of this same plant a Feliks-256 computer has been used to optimize the loading process, resulting in an increase of 10 per cent in equipment efficiency.

At the Republica Pipe Enterprise, production has been increased by 2,000 tonnes a year following optimization of equipment control by means of a Feliks-512 computer.

The use of a computer for automatic analysis of blast-furnace charges at the Reşiţa Steelworks has led to savings of raw materials and energy valued at 500,000 lei annually.

USSR. At the 5,000 m^3 blast-furnace of the Krivoy Rog Iron and Steel Plant the management has introduced an automatic charge and charge-feed control system using a control centre built around an M-6000 computer. The annual savings achieved as a result of this measure have totalled 1,040,000 roubles in the form of a reduction of specific coke consumption by 5.5 kg per tonne of iron. The basic oxygen converter shop of the Novolipetsk Iron and Steel Works has placed in operation a system for the automated control of the converter melt process which is operated from a control centre based, again, on an M-6000 computer. Calculated in terms of the basic oxygen converter shop alone, savings have amounted to about 900,000 roubles a year as a result of an increase of 20 per cent in the proportion of melts produced from the first furnace run, an increase of 3 per cent in shop productivity, a reduction in the consumption of alloying elements and a lengthening of liner life. At medium-section mill 450 of the West Siberian Iron and Steel Works an automated control system has been introduced which, through the use of four M-6000 computers, makes it possible to monitor the passage of the metal, control the operation of the mill, lay out the stock and realign the mill for the rolling of sections of different size. This system has produced annual savings of some 2 million roubles by increasing the productivity of the mill by 150,000 tonnes a year.

Czechoslovakia. In 1976 the Klement Gottwald Iron and Steel Works put into operation a central coal management system for coke by-product production. With the system in operation for two years, there has been a substantial

improvement in the organization and management of coal-handling operations as marked by higher productivity and a significant reduction in working personnel. Yearly savings have totalled 9.6 million korunas.

Partial automation has been introduced for the operation of blast-furnace No. 4 at the Viktowice Iron and Steel Works. Initial results have shown that coke consumption can be reduced by approximately 18 per cent, furnace efficiency increased by 14 per cent and iron quality improved. Given the current yearly level of iron production at 11,830,000 tonnes, annual savings amount to 91.8 million korunas.

In early 1977 this same plant introduced a control system for its 3,500 four-high mill. This measure is bringing an over-all annual savings of 18.7 million korunas through 5-per-cent greater productivity, 2-per-cent greater yield, the lowering of the rejection rate by 1.2 kg per tonne, and energy savings of 1 per cent.

Also in 1977 the "Great October Socialist Revolution" Steelworks at Trinec installed a blank-cutting system for use with its continuous-action billeting mill. This system has made it possible to achieve average annual savings of 11.2 million korunas as a result of a reduction of 2 per cent in waste.

Still in the design stage at the East Slovak Iron and Steel Combine is an automated system for the control of basic oxygen converter shop No. 2. Preliminary data suggest annual savings of about 16.5 million korunas through an increase in productivity of 2 to 4 per cent, a reduction of 1 per cent in casting losses and of 1.5 to 2 kg per tonne in loss on ignition, as well as an extension of lining life by 30 to 40 melts.

Yugoslavia. The Ravne Steelworks has installed a PDP 11/40 and 11/05 control computer to develop and introduce a system for the automatic control of the melt process in its electric arc furnaces. Under operating conditions, the system has demonstrated excellent performance characteristics in reducing ferroalloy and energy consumption and in ensuring a better error rate in the make-up of the charge. The investment costs for the creation of this system were recovered, mainly through the reduced ferroalloy consumption, over a period of 4 to 6 months, before the whole system had been installed and while it was not yet thoroughly familiar to plant personnel.

By introducing a system for the centralized monitoring and control of electric power and gas distribution, the State Iron and Steel Works at Zenica has succeeded not only in reducing power consumption at peak load periods, but also in cutting back gas consumption by altering the gas balance of the plant. It is expected that this system will pay for itself in five years.

Major directions in the further development of iron and steel industry automation

Looking ahead, it is clear that the most essential condition for continued advances in iron and steel industry automation is to ensure compliance with the principal prerequisites of automation as expressed in the form of the requirements to be met by production processes and equipment and by the level of mechanization of these processes and equipment. The most important factors in this connexion are:

- Standardization and uniformity of quality of basic raw materials, blanks and billets, semi-finished products and power apparatus;
- The maintenance of a steady and uninterrupted pace in the performance of production operations;
- The performance of an entire technological process or the maximum possible number of technological operations on a flow-line basis;
- the availability, when analysing a process, of a mathematical model (mathematical description) capable of accounting for its technological features with sufficient thoroughness to permit the formulation of a process-control algorithm;
- The specializatonn of equipment to turn out as limited a range of products as possible;
- Technological standardization based on equipment of the same type;
- High equipment reliability guaranteed not to fall below a fixed permissible level during periods between scheduled repair;
- Equipment so designed as to make possible the installation of, and unimpeded maintenance access to, automation systems and devices, together with the technical conditions needed to ensure the possibility of operating such systems;
- The mechanization of all labour-intensive operations involved in ensuring the proper timing and sequencing of technological operations and the performance of the technological process on a flow-stream basis.

Specialists engaged in introducing automation systems at iron and steel plants should keep in mind the following considerations when determining the extent to which the equipment should be automated:

- High-efficiency, fully mechanized equipment of high unit productivity based on new technology should be automated on a comprehensive basis through the use of computers; this corresponds to the optimal level of automation;
- Modern, partially mechanized equipment of high and medium unit productivity currently in operation should be automated through the use of computers, but at a less-than-optimal level;
- Unmechanized, non-redesignable equipment of low and medium unit productivity currently in operation should be equipped with individual control devices and local automation systems.

On the basis of an analysis of the long-range development trends in the iron and steel industry, the current situation with regard to automation in this branch and the work accomplished in implementation of the measures recommended by the Fifth International Conference, it is possible to identify the principal technical innovations that may be expected. These are:

- The introduction of ASCTP systems for the principal metallurgical processes;
- The development and introduction of new high-performance instruments and devices for the monitoring of technical parameters, particularly the geometrical dimensions and quality of finished products, the composition of gases, raw materials and metals, and weight at various stages of the production process;
- The introduction of comprehensive automated control systems for large production units, such as basic oxygen converter shops, electric steelmaking shops with continuous-casting sections, and rolling shops;
- The design and installation of full-cycle automated production-control systems for comprehensive plant management;
- The development of high-capacity computation centres, including collectively operated centres, as a basis for the computerization and automation of iron and steel works (including such aspects as the formulation of a single set of basic standards, standardized document-handling procedures and specialist training);
- The further development of branch-wide automated control systems to constitute the basic level of the over-all national economic management structure.

Experience in the operation of automated systems at various management levels indicates that management efficiency can be substantially improved by co-ordinating and meshing the work of these systems.

The objective prerequisites for the design and introduction of comprehensive production-control systems in the iron and steel industry are:

- Past experience in the design and operation of ASCTP and APCS systems;
- The presence of a technical support base including modern computers backed by a full range of peripheral equipment and communication links to permit the real-time collection and storage of information, and the availability of a wide assortment of the local automation systems and devices required for process control and communication with the computer centres.

Over the long term the following tasks remain to be solved in connexion with the design of comprehensive automated control systems for the iron and steel industry:

- The development of integrated data-processing systems;
- The design of highly reliable real-time CACS systems;
- The introduction of operational systems designed to combine the data-processing function with process and production control.

Measures for the further development of the automation of production processes and control functions in the iron and steel industry

In order to ensure successful continued progress in the automation of process and production control in the iron and steel industry, the Conference considers it necessary that the following measures should be carried out over the next few years:

1. In the area of pelletizing plant operations

1.1. To complete the development of, place in operation, and master the use of, automated systems for the control of high-capacity conveyer equipment for pellet sintering and firing;

1.2. To develop an automated system for determining the quality characteristics of charge materials on the basis of automatic sampling, conveyance and X-ray spectral analysis of the samples;

1.3. To carry out fundamental research into the processes of pellet sintering and firing in order to develop a mathematical description and, on that basis, an optimization algorithm for these processes;

1.4. To develop and implement a set of measures, using modern econometric techniques, for blending starting materials and charges;

1.5. To design basic technological equipment with an eye to the requirements of automation;

1.6. To speed the development and improvement of the following systems and devices:

- High-accuracy weight-batchers and scales for use with charge materials and finished products;
- Monitoring instruments for use in checking the physical and mechanical properties of sinter and pellets;
- Systems for the automatic acceptance and distribution of the sintering mixture and its components, with continuous monitoring of the hopper fill level;
- Systems for monitoring and controlling the gas-dynamic characteristics of the sinter mixture and raw pellet layer on the pallets of the sintering and pellet-firing equipment.

2. In the area of blast-furnace operations

2.1. To continue working towards the optimal level of blast-furnace automation (i.e. the level of automation resulting in the greatest savings in furnace operation);

2.2. To provide for the extensive use of numerical systems for the automatic monitoring and control of the batching of all furnace charge components, and also systems for automatically monitoring the coke moisture content and controlling the batching of coke furnace-loaded according to the "dry weight" principle;

2.3. To speed the development of apparatus and devices for the on-line taking and preparation of representative charge material samples;

2.4. To arrange for the series-production and extensive introduction of apparatus to measure the temperature of the hot blast to 1,500° C and for the contact-free monitoring of the temperature in the hoods of blast heaters to 1,700° C;

2.5. To continue work on the improvement and introduction of monitoring and control systems for the purpose of developing a computer-assisted system for the comprehensive automation of blast-furnace operation, paying specific attention to the following aspects:

- The preparation and delivery of the charge, including the loading of the charge hopper, the blending of all components and their automatic analysis, the loading of the furnace and the distribution of the materials around the furnace top;
- The gas flow distribution across the furnace stack;
- The control of the thermal performance of the furnace;
- The optimal heating of the blast heaters.

3. <u>In the steelmaking area</u>

The automation of steelmaking processes must provide for:

- The extensive use of crane scales and other types of electronic scales at steel foundries;
- The extensive use of high-accuracy thermocouples for steel temperature measurements;
- The development and introduction of automated systems for the taking, conveyance and preparation of metal samples for multi-component analysis.

In respect of the methods for the melting and continuous casting of steel, the Conference considers it necessary to carry out the following measures:

3.1. Basic oxygen converter steelmaking

3.1.1. To continue the equipping of converters with automatic systems and devices in line with rational levels of automation;

3.1.2. To make wide use of test probes for temperature measurements and carbon content readings in the bath without the need to interrupt converter operation, and also of slag-forming monitors;

3.1.3. To complete the development of systems to analyse the composition of converter gases following wet scrubbing;

3.1.4. To equip converters from which gases are tapped without after-burning with systems to analyse the composition and flow rate of the gases by means of mass-spectrometers, and converters with gas after-burning with gas composition monitoring systems based on individual gas analysers;

3.1.5. To continue the refinement of the mathematical algorithms for the static and dynamic control of oxygen-converter steelmaking.

3.2. Open-hearth steelmaking and twin-bath steelmaking equipment

To continue work on the introduction of local systems to control:

- The position of the oxygen lances;
- The batching of ferroalloys at the time they are fed into the ladle;
- The flow rate of the oxygen and natural gas.

3.3. Electric steelmaking

3.3.1. To speed the development of a computerized system to provide automatic operating control of electric arc furnaces (EAF);

3.3.2. To continue the equipping of EAF with automation systems consistent with a rational level of automation;

3.3.3. To make wider use on EAF of thyristor-controlled power regulators, programmed power-supply control systems, metal and furnace-lining temperature monitors, quantometers, and high-speed apparatus for the sulphur and carbon analysis of steel;

3.3.4. To develop automated systems to control the performance of electroslag remelting units;

3.3.5. To make wider use on vacuum-arc furnaces of automatic arc-gap regulators and automatic helium-pressure control systems;

3.3.6. To continue work on the development of new systems for automatic process control in plasma-arc furnaces, cathode-ray apparatus, induction vacuum furnaces and arc furnaces during the remelting of metallized pellets.

3.4. Continuous steel casting

3.4.1. To make wider use of computer-assisted systems for the automation of continuous-casting units;

3.4.2. To make wider use in continuous-casting shops of turn-table ladle-weighing systems with readings displayed on large-sized digital indicator boards;

3.4.3. To complete the development of, and introduce, a mathematical algorithm for optimal lay-out of billets on high-efficiency curved continuous-casting machines operating according to the "melt-on-melt" casting method;

3.4.4. To make wide use of automatic monitoring and control systems for maintaining a prescribed level of metal in the mould;

3.4.5. To develop and introduce automatic systems for monitoring and controlling the cooling of the metal in the secondary cooling zone.

4. Ferroalloy production

4.1. To speed the development of computer-assisted automated systems for the control of the electrical and technical performance of large ferro-alloy furnaces;

4.2. To complete the development and initiate the extensive use of the following automation instruments, systems and devices:

- For the analysis of the chemical composition of charge materials and ferroalloys;
- For the analysis of furnace top gases;
- For the on-stream analysis of carbon content in coke and semi-coke fines;
- For the continuous and intermittent blending of the charge components;

4.3. To introduce more extensively the following automation devices:

- Thyristor-controlled power regulators for electric refining furnaces;
- Power regulators for ore-reduction furnaces;
- Scale-equipped systems for the adaptive blending of charge components.

5. Rolled products and pipe

As part of the effort to automate the technological processes involved in the manufacture of rolled products, comprehensive computer-assisted systems for the automated control of high-efficiency rolling mills must be developed and introduced to function in conjunction with local systems capable of being independently operated.

5.1. Plate production

To continue work on the design and introduction of integrated systems for the control of plate mills in order to provide comprehensive solutions to the following problems:

- The processing of incoming orders for steel plate and the selection of the appropriate rolling technology;
- The selection of slabs and ingots to ensure the maximum yield;
- Optimal control of the heating of the metal in the heating furnace;
- The selection of the optimal rolling sequence to ensure the fullest possible use of the rolling time and the production of high-quality plate;
- The calculation of the reduction and lay-out programme;

- The monitoring of plate progress over the segment "slab yard - hot squaring shears";
- The adaptive control of the rolling process so as to produce plate of prescribed width, thickness and length with a minimum number of passes, consistent with technological constraints;
- Plate rolling in the optimum temperature range.

5.2. Sheet production

5.2.1. To speed the development and introduction of comprehensive computer-assisted mill control systems;

5.2.2. To develop and introduce systems for the combined control of strip thickness and shape on hot-rolling mills, and for the optimal control of tension between stands in order to minimize discrepancies from the desired geometry of the hot-rolled strip;

5.2.3. To design new and improve existing devices for measuring strip shape on hot and cold rolling mills;

5.2.4. To develop systems for the combined control of the "furnace-mill" complex for the purpose of increasing the productivity of this complex and of rationalizing the monitoring of temperature during strip heating and rolling;

5.2.5. To improve control of the strip cooling process within the finishing stand group and on the run-out table;

5.2.6. To design devices for monitoring the temperature of the metal in the working chamber of the heating furnace;

5.2.7. To make wider use of systems for determining the theoretical weight of rolled stock both in rolling mills and in cutting units;

5.2.8. To develop a set of algorithmic modules to describe technological processes and solve problems relating to the control of the heating of the metal and its rolling in the mill;

5.2.9. To develop roller position sensing devices;

5.2.10. To develop no-contact sensors for monitoring strip length and speed;

5.2.11. To develop automation systems and devices for use with the new high-productivity endless rolling mills;

5.2.12. To develop a system for the comprehensive control of the stand force factors (screw-down mechanism, roller bend and counter-bend, preliminary stand tension) affecting the strip, as well as devices for the reliable and accurate measurement of all the forces acting in the stand and on the strip.

5.3. Production of rolled shapes and sections

5.3.1. To develop standard computer-assisted systems for the automatic control of screw-down mechanisms, operating speed, cutting, theoretical weight calculations and cooling processes as applied to rolled products;

5.3.2. To speed work on the design and introduction of systems for automatically controlling the set up of the mill for prescribed shape sizes and for adaptively correcting the mill in response to actual deviations in shape;

5.3.3. To expand the effort to develop and introduce systems for the automatic control of the billet heating process and of billet feed on the basis of the rolling rate;

5.3.4. To expand the effort to develop and introduce systems for the automatic control of the deburring and cut-out processes before the stock reaches the cooler;

5.3.5. To make wider use of automatic non-destructive testing for surface and internal flaws in rolled sections and shapes (round and square billets).

5.4. Pipe production

5.4.1. To speed the development of standard systems of automated control for uniform production units, particularly for continuous mill lines, e.g. type 30-102, and longitudinal stand lines, type 140;

5.4.2. To develop, on the basis of previously designed local systems, comprehensive control systems for use with pipe-rolling units and shops as a whole, specifically for the following functions:

- Optimal lay-out and grading of skelp;
- Control of three-roller reeling mills;
- Thermal control of rotary-ring furnaces;
- Control of the rolling process in the production of pipe with reduced wall thickness at the ends;
- Regulation of roller rotating speed on reeling mills;
- Monitoring and control of wall thickness and pipe tension;

5.4.3. To develop local systems for the automation of pipe-welding stands;

5.4.4. To continue work on the development and introduction of automatic pipe quality-control systems and product inventory systems based on theoretical weight;

5.4.5. To continue work on the development of automated flow-lines for pipe finishing and quality control;

5.4.6. To continue work on the development and introduction of systems for the automated control of pipe cold-rolling mills;

5.4.7. To continue work on the development of sensors for the following parameters:

- Position of the metal in rotary-ring furnaces;
- Biting of the pipe by the mill rollers;
- Distance between rollers in the contraction zone;
- Distance between guide-bars;
- Position of the mandrel and alignment of the cutting tool of the broaching and shaping press;

5.4.8. To make wider use of automatic non-destructive-quality-control of hollow conversion skelp before the pipe is cold-rolled and drawn.

5.5. Automation devices for the production of rolled products and pipe

The Conference considers it necessary to continue work on the design, improvement and production of special-purpose devices for the comprehensive automation of rolled product and pipe production, including:

- Apparatus for the on-stream weighing of hot and cold billets;
- Instruments for measuring the wall thickness of hot and cold rolled pipe;
- Gauges for measuring the coating thickness of moving steel strips;
- Instruments for measuring the cross-section of square blanks, slabs and rolled shapes;
- Instruments for measuring length during rolling and for estimating the length of pipes and small sections;
- Automatic flaw-detectors for the detection and recording of internal defects in strip steel, for use with cutting units and continuous pickling lines;
- Equipment systems for the on-line inspection of metal products for internal flaws in the production of rolled shapes and sections;
- Equipment systems for the on-line inspection and grading of seamless and welded pipe;
- Computer-assisted high-performance X-ray thickness gauges for use with wide-strip hot and cold rolling mills;
- High-accuracy high-speed radioactive thickness gauges for monitoring the thickness of cold-rolled products;
- Radioactive thickness gauges for use with non-metallic coatings.

6. Automated control of metallurgical production processes and the development of computer centres in the iron and steel industry

Present-day trends with respect to the automation of control functions in the iron and steel industry are linked to the creation of integrated control systems which combine the solution of process-control and production-management problems. Contributing to this development is the ever increasing use, at plants and mills, of third-generation computers equipped with modern peripheral systems for control functions.

The Conference considers it necessary:

6.1. To continue research into integrated control in the iron and steel industry with the aim of making more effective use of computer engineering and determining the principles and methods for the design and introduction of integrated control systems;

6.2. To expand the effort to make more effective use of computer engineering through the wider application of optimization techniques, real-time control systems, etc.;

6.3. To continue programmes of automated control in the iron and steel industry on the basis of a unified system of computers for the purpose of developing and later disseminating standard design solutions for enterprises of the same type, functional subsystems and control techniques; to expand exchange programmes involving the sharing of standard designs among the CMEA countries and Yugoslavia;

6.4. To continue the development of computer centres at iron and steel plants as the basis of the automated control systems at these enterprises, and to proceed to the planning of branch-wide networks of such centres;

6.5. To continue research aimed at finding advanced and effective solutions to automation problems in the iron and steel industry (for example, control system decentralization, the use of systems of direct numerical control, etc.).

7. Research and development programmes in the area of automation and production control in the iron and steel industry

In order to continue to meet the challenge of process automation and production control in the iron and steel industry, the Conference considers it necessary that the research and development effort of the next few years should be directed at the following objectives:

7.1. The detailed description of the rational levels of automation for metallurgical production units and installations in the light of the need to develop integrated automatic control systems and keeping in mind

the cost-effectiveness of the systems currently in operation, this determination to be carried out on a periodical basis in the future;

7.2. The preparation and publication of a catalogue of automation systems and devices for the iron and steel industry;

7.3. Standardization in the area of data systems and data-processing;

7.4. The development of the principles, methods and technical means for quality-control at all stages of the production cycle;

7.5. The development of the organizational structures and methodological principles for the installation, both at the individual plant level and throughout the branch, of comprehensive quality-control systems in the iron and steel industry;

7.6. The carrying out of research and development programmes on the use of mini-computers and micro-computers in the design of ASCTP and APCS systems for process and production control;

7.7. The formulation of specifications for the mini-computers and micro-computers to be developed, these specifications being geared to iron and steel industry applications;

7.8. The development of methods for the design of adaptive control systems and direct numerical control systems for governing the complex processes of rolled metal and pipe production;

7.9. The carrying out of research and development programmes on methods for optimizing the performance of automated units and facilities in the iron and steel industry;

7.10. The formulation of the social and methodological principles to permit the rational interaction of man and computer in man-machine automated control systems, specific attention being paid to the elaboration of decision-making procedures and methods for the formal description and construction of mathematical models for the simulation of metallurgical installations and control processes;

7.11. The formulation of the methodological principles for optimal production planning and management based on econometric techniques and systems analysis;

7.12. The formulation of methodological principles to ensure the organizational, technical and programme-related compatibility of computer centres and automatic control systems at different levels;

7.13. The carrying out of research to determine the reliability and efficiency of prototypes of automatic control systems designed to operate at different levels;

7.14. The compilation of a list of successfully operating automatic control systems to serve as a basis for the development of standard designs for similar systems to be used at various levels of control.

The Conference considers it necessary that the specialized organizations and enterprises of the instrument-manufacturing and engineering industries should be called upon to assist in the development and improvement of automation systems and devices for the iron and steel industry and in organizing the production of these items.

The Conference also considers it necessary that courses for the training of programmers for various branches of industry should be organized at computer-manufacturing enterprises.

Further co-operation between the CMEA countries and Yugoslavia in the area of iron and steel industry automation and the improvement of the forms and methods of work of the Automation Section

The comprehensive programme for the continued strengthening and improvement of co-operation among the CMEA countries and the development of socialist economic integration between them calls for further advances in the automation of the iron and steel industry (section 10, page 22).

The Conference considers it advisable that co-operation between the CMEA countries and Yugoslavia in the automation area should be expanded on the basis of long-term co-operative programmes (extending over 4-5 years).

Regarding improvement of the forms and methods of work, the Conference considers it necessary:

1. To improve the co-ordination of scientific and technical co-operation between the CMEA countries and Yugoslavia in the area of process automation and production control through more extensive division of labour, clearer formulation of the objectives of the research programmes, and the introduction of specific time-tables for information exchanges on research results;

2. To expand co-operation and formulate more specific lines of specialization between the CMEA countries and Yugoslavia in the development and manufacture of the automation systems and devices required for process and production control in the iron and steel industry, with particular emphasis on the area of quality control;

3. To continue and strengthen the existing practice of exchanging information on scientific and technological achievements and advanced production experience;

4. To expand and strengthen direct bilateral and multilateral contacts on scientific and technological matters between organizations and enterprises in the CMEA countries and Yugoslavia;

5. To develop scientific and technical forecasts regarding automation in the CMEA countries and Yugoslavia on a long-range basis (to the year 2000);

6. To organize specialized seminars on specific major problems in the field of automation, with discussions of scientific papers and articles;

7. To organize temporary working groups of experts to exchange information, study, and make recommendations on, specific areas of automation of the most current interest;

8. To organize scientific conferences to consider projects for the comprehensive automation of large, modern iron and steel facilities and production units where there is the possibility that such projects might provide a basis for standard solutions;

9. To exchange information on the results of scientific and technical programmes carried out in the individual countries, including data on automatic control systems algorithms and computer programmes developed in the CMEA countries and Yugoslavia;

10. To conduct joint scientific and technical research in the area of process automation and production control in the iron and steel industry.